

SYLLABUS & PROGRAMME STRUCTURE

Physics

(Honours)

(Choice Based Credit System)

(Effective from the Academic Session 2017-2018)

Fifth Semester

MAHARAJA BIR BIKRAM UNIVERSITY
AGARTALA, TRIPURA: 799004

PROGRAMME STRUCTURE**Structure of Proposed CBCS Syllabus B.A / B.Sc / B.Com Honours**

Semester	Core Course (14) Honours	Ability Enhancement Compulsory Course (AECC) (2)	Skill Enhancement Course (SEC) (2)	Discipline Specific Elective (DSE) (4)	Generic Elective (GE) (4)
1	C1 C2	AECC1: Environmental Science			GE1 (Paper-I of selected subject other than Hons subject)
2	C3 C4	AECC2 : (English/MIL (Communication)			GE2 (Paper-II of selected subject other than Hons subject)
3	C5 C6 C7		SEC1		GE3 (Paper-III of selected subject other than Hons subject)
4	C8 C9 C10		SEC2		GE4 (Paper-IV of selected subject other than Hons subject)
5	C11 C12			DSE1 DSE2	
6	C13 C14			DSE3 DSE4	

Semester – V
Core Course – Paper – XI
QUANTUM MECHANICS AND ITS APPLICATIONS
(Credits: Theory-04, Practicals-02)
Marks: Theory-70 (60 + Inter: 10), Practical-30 (20 + Inter: 10)

Unit – I

[15 +3 (Intro.+ Recap. + Problem hints/ Practice) Lectures]

Time dependent and time independent Schrodinger equation: Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Probability and probability current densities in three dimensions; Expectation values of position and momentum.

Ehrenfest theorem, eigen functions and eigen values, stationary states, orthogonality of eigenfunctions, normalization, fundamental postulates of quantum mechanics, Hermitian property. Commutator of position and momentum operators; Wave Function of a Free Particle in 3D.

General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wave function; Uncertainty principle: Position-momentum/energy-time.

Unit – II

[15 +3 (Intro.+ Recap. + Problem hints/ Practice) Lectures]

Applications of Q M: bound states in an arbitrary potential, Hydrogen Atom: Bound state; Continuity of wavefunction, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; ground state, zero point energy; Hydrogen atom problem: solution of time independent Schrodinger equation in spherical polar coordinates by method of separation of variables (radial and spherical wave functions); shapes of the wave functions and probability densities for ground & first excited states.

Unit – III

[15 +3 (Intro.+ Recap. + Problem hints/ Practice) Lectures]

Application of QM: Hydrogen Spectrum ,Atoms in Electric & Magnetic Fields: Continuous and characteristics X-ray spectra, Mosley's law and its explanation from Bohr's theory.

Spectrum of hydrogen atom with reduced mass correction, vector atom model, space quantization, Electron angular momentum. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect (Qualitative Discussion only).

Unit – IV

[15 +3 (Intro.+ Recap. + Problem hints/ Practice) Lectures]

Many electron atoms and Application Of QM in Spectroscopy: Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Spin-orbit coupling in atoms-L-S and J-J couplings. Lande g factor, Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.).

Basic ideas about molecular spectra, rotational and vibration spectra of diatomic molecules, Raman Effect and its application.

N.B: Simple Problems (covering Unit-I, II, III & IV) using formulae of these respective units to be practiced.

Suggested Readings:

1. *A Text book of Quantum Mechanics*, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
2. *Quantum Mechanics*, Robert Eisberg and Robert Resnick, 2ndEdn., 2002, Wiley.
3. *Quantum Mechanics*, Leonard I. Schiff, 3rdEdn. 2010, Tata McGraw Hill.
4. *Quantum Mechanics*, G. Aruldas, 2ndEdn. 2002, PHI Learning of India.
5. *Quantum Mechanics*, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
6. *Quantum Mechanics: Foundations & Applications*, Arno Bohm, 3rdEdn., 1993, Springer
7. *Quantum Mechanics for Scientists & Engineers*, D.A.B. Miller, 2008, Cambridge University Press

Additional Books for Reference

1. *Quantum Mechanics*, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
2. *Introduction to Quantum Mechanics*, D.J. Griffith, 2ndEd. 2005, Pearson Education
3. *Quantum Mechanics*, Walter Greiner, 4thEd., 2001, Springer

PRACTICAL Core Course – Paper – XI

Marks – 30

Use C++/Scilab for solving the following problems based on Quantum Mechanics like

1. Solve the s-wave Schrodinger equation for the ground state and the first excited state of the hydrogen atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2} [V(r) - E] \text{ where } V(r) = -\frac{e^2}{r}$$

Here, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take $e = 3.795$ (eVÅ)^{1/2}, $\hbar c = 1973$ (eVÅ) and $m = 0.511 \times 10^6$ eV/c².

2. Solve the s-wave radial Schrodinger equation for an atom:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2} [V(r) - E]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential

$$V(r) = -\frac{e^2}{r} e^{-r/a}$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take $e = 3.795$ (eVÅ)^{1/2}, $m = 0.511 \times 10^6$ eV/c², and $a = 3$ Å, 5 Å, 7 Å. In these units $\hbar c = 1973$ (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

3. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2} [V(r) - E]$$

For the anharmonic oscillator potential

$$V(r) = \frac{1}{2} kr^2 + \frac{1}{3} br^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose $m = 940$ MeV/c², $k = 100$

MeV fm^{-2} , $b = 0, 10, 30 \text{ MeV fm}^{-3}$ In these units, $\hbar c = 197.3 \text{ MeV fm}$. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

4. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{\hbar^2} [V(r) - E]$$

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D(e^{-2\alpha r'} - e^{-\alpha r'}), \quad r' = \frac{r - r_0}{r_0}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: $m = 940 \times 10^6 \text{ eV}/c^2$, $D = 0.755501 \text{ eV}$, $\alpha = 1.44$, $r_0 = 0.131349 \text{ \AA}$

Laboratory based experiments: (optional, depending on availability of instruments)

5. Study of Electron spin resonance- determine magnetic field as a function of the resonance frequency
6. Study of Zeeman effect: with external magnetic field; Hyperfine splitting
7. To show the tunneling effect in tunnel diode using I-V characteristics.
8. Quantum efficiency of CCDs

Reference Books:

- Schaum's outline of Programming with C++. J.Hubbard, 2000, McGraw-Hill Publication
- Numerical Recipes in C: The Art of Scientific Computing, W.H. Press et al., 3rd Edn., 2007, Cambridge University Press.
- An introduction to computational Physics, T.Pang, 2nd Edn., 2006, Cambridge Univ. Press
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific & Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer.
- Scilab (A Free Software to Matlab): H. Ramchandran, A.S. Nair. 2011 S. Chand & Co.
- A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
- Scilab Image Processing: L.M. Surhone. 2010 Betascript Publishing ISBN: 978-6133459274

Semester – V
Core Course – Paper – XII
SOLID STATE PHYSICS

(Credits: Theory-04, Practicals-02),

[Marks: Theory- 70 (60 + Inter: 10), Practical-30 (20 + Inter:10)]

Unit – I

[15 +3 (Intro.+ Recap.+ Problem hints/ Practice) Lectures]

Crystal Structure:Crystalline and amorphous solids, translational symmetry, classification of crystalline solids, elementary ideas about crystal structure, concept of lattices and basis, Unit cell, Primitive cell, fundamental types of lattices, Miller indices, simple cubic, b.c.c. and f.c.c. lattices, Reciprocal Lattice. Brillion Zones.Laue and Bragg's equations,Bragg's Law, Powder diffraction method, study of NaCl&KCl structure, Atomic and Geometrical Factor. Different types and natures of binding: ionic, covalent, molecular, metallic and Vander walls.

Unit – II

[15 +3 (Intro.+ Recap.+ Problem hints/ Practice) Lectures]

Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Mono-atomicand Diatomic Chains, Acoustical and Optical Branch, qualitative description of the phonon Spectrum in Solids. Dulong-Petit's Law, Einstein and Debye theories of specific heat of solid, T^3 law, Wiedmann-Franz law. Free electron theory of metals, effective mass, drift velocity, mobility and conductivity

Unit – III

[15 +3 (Intro.+ Recap.+ Problem hints/ Practice) Lectures]

Elementary band theory: Modification of electronic energy levels of atoms in a crystalline solid: Band structure of electronic states: Kronig-Penny model, distinction between metals, insulators and semi conductors, qualitative discussion on n and p-type semi conductors, Hall Effect in both conductor and in semi conductors. Measurement of conductivity (04 probe method) & Hall coefficient

Superconductivity: Experimental Results, Critical Temperature, Critical magnetic field,Meissner effect. Type I and type II Superconductors, London's Equation and Penetrationidea of BCS theory (No derivation)

Unit – IV

[15 +3 (Intro.+ Recap.+ Problem hints/ Practice) Lectures]

Magnetic Properties of Matter: Dia, Para, Ferriand Ferromagnetic Materials, Classical Langevin's Theory of diaand Paramagnetic theory, Quantum MechanicalTreatment of Paramagnetism, Curie's law, Weiss's Theory of Ferromagnetism andFerromagnetic Domains, Curie-Weiss Law, Discussion of B-H Curve. Hysteresis and Energy Loss.

Dielectric Properties of Materials: Polarization, Local Electric Field at an Atom, Depolarization Field, Electric Susceptibility, Polarizability, Clausius Mosotti Equation, Classical Theory of Electric Polarizability.

Ferroelectric Properties of Materials: Structural Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop. (No derivation required)

N.B: Simple Problems (covering Unit-I, II, III & IV) using formulae of these respective units to be practiced.

Suggested Readings:

1. *Introduction to Solid State Physics*, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
 2. *Elements of Solid State Physics*, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
 3. *Introduction to Solids*, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
 4. *Solid State Physics*, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
 5. *Solid-state Physics*, H. Ibach and H. Luth, 2009, Springer
 6. *Solid State Physics*, Rita John, 2014, McGraw Hill
 7. *Elementary Solid State Physics*, I/e M. Ali Omar, 1999, Pearson India
 8. *Solid State Physics*, M.A. Wahab, 2011, Narosa Publications
 9. *Introduction to Solid State Physics*, S P Kuila.
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PRACTICAL

Core – Course – Paper – XII

Marks - 30

1. Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method)
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency
5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR)
6. To determine the refractive index of a dielectric layer using SPR
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
9. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150°C) and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.
11.
 - a. To draw the characteristics of a p-n junction diode for current under reverse bias and temperature.
 - b. To find the band gap of the semi-conductor material.

Suggested Readings :

1. *Advanced Practical Physics for students*, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
 2. *Advanced level Physics Practicals*, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
 3. *A Text Book of Practical Physics*, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
 4. *Elements of Solid State Physics*, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India.
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Semester – V
DSE – Paper – I (Honours)
NUCLEAR AND PARTICLE PHYSICS

[Credits: Theory-05, Tutorials-01]

[Marks: Theory- 80, Tutorial- 20]

The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Unit I:

[Including (Intro.+ Recap. + Problem hints/ Practice) 20 Lectures)]

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excited states.

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

Unit II:

[Including (Intro.+ Recap. + Problem hints/ Practice) 20 Lectures)]

Radioactivity decay : (a) Alpha decay: basics of α -decay processes, theory of α -emission, Gamow factor, Geiger Nuttall law, α -decay spectroscopy. (b) β -decay: energy-kinematics for β decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion.

Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

Unit III:

[Including (Intro.+ Recap. + Problem hints/ Practice) 20 Lectures)]

Interaction of Nuclear Radiation with matter: Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, photoelectric effect, Compton scattering, pair production, neutron interaction with matter.

Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photomultiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

Unit IV:

[Including (Intro.+ Recap. + Problem hints/ Practice) 20 Lectures)]

Particle Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons.

Particle physics: Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Iso-spin, Strangeness and charm, concept of quark model, color quantum number and gluons.

N.B: Simple Problems (covering Unit-I, II, III & IV) using formulae of these respective units to be practiced.

Suggested Readings:

1. *Introductory nuclear Physics* by Kenneth S. Krane (Wiley India Pvt. Ltd., 2008).
 2. *Concepts of nuclear physics* by Bernard L. Cohen. (Tata Mcgraw Hill, 1998).
 3. *Introduction to the physics of nuclei & particles*, R.A. Dunlap. (Thomson Asia, 2004).
 4. *Introduction to High Energy Physics*, D.H. Perkins, Cambridge Univ. Press
 5. *Introduction to Elementary Particles*, D. Griffith, John Wiley & Sons
 6. *Quarks and Leptons*, F. Halzen and A.D. Martin, Wiley India, New Delhi
 7. *Basic ideas and concepts in Nuclear Physics - An Introductory Approach* by K. Heyde (IOP-Institute of Physics Publishing, 2004).
 8. *Radiation detection and measurement*, G.F. Knoll (John Wiley & Sons, 2000).
 9. *Physics and Engineering of Radiation Detection*, Syed Naeem Ahmed (Academic Press, Elsevier, 2007).
 10. *Theoretical Nuclear Physics*, J.M. Blatt & V.F. Weisskopf (Dover Pub.Inc., 1991)
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Semester – V
DSE – Paper – II (Honours)
ADVANCED MATHEMATICAL PHYSICS

[Credits: Theory-05, Tutorial-01]

[Marks: Theory- 80, Tutorial- 20]

The emphasis of the course is on applications in solving problems of interest to physicists. Students are to be examined on the basis of problems, seen and unseen.

Unit – I

[Including (Intro.+ Recap.+ Problem hints/ Practice) 20 Lectures)]

Matrices and Eigen-value Problems:

Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar and Unit Matrices. Upper-Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew- Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Trace of a Matrix.InnerProduct.

Eigen-values and Eigenvectors. Cayley- Hamilton Theorem. Diagonalization of Matrices. Solutions of Coupled Linear Ordinary Differential Equations. Functions of a Matrix.

Unit – II

[Including (Intro.+ Recap.+ Problem hints/ Practice) 20 Lectures)]

Linear Vector SpacesAnd Introduction to Cartesian Tensors:

Abstract Systems. Binary Operations and Relations. Introduction to Groups and Fields. Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformations. Algebra of Linear Transformations. Non- singular Transformations. Representation of Linear Transformations by Matrices.

Cartesian Tensors

Transformation of Co-ordinates. Einstein's Summation Convention. Relation between Direction Cosines. Tensors. Algebra of Tensors. Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Invariant Tensors : Kronecker Alternating Tensors. Association of Antisymmetric Tensor of Order Two and Vectors.

Unit – III

[Including (Intro.+ Recap.+ Problem hints/ Practice) 20 Lectures)]

Group Theory:

Review of sets, Mapping and Binary Operations, Relation, Types of Relations.

Groups: Elementary properties of groups, uniqueness of solution, Subgroup, Centre of a group, Co-sets of a subgroup, cyclic group, Permutation/Transformation. Homomorphism and Isomorphism of group. Normal and conjugate subgroups, Completeness and Kernel. Some special groups with operators. Matrix Representations: Reducible and Irreducible.

Unit – IV

[Including (Intro.+ Recap.+ Problem hints/ Practice) 20 Lectures)]

Advanced Probability Theory:

Fundamental Probability Theorems. Conditional Probability, Bayes' Theorem, Repeated Trials, Binomial and Multinomial expansions. Random Variables and probability distributions, Expectation and Variance, Special Probability distributions: The binomial distribution, The poisson distribution, Continuous distribution: The Gaussian (or normal) distribution.

N.B: Simple Problems (covering Unit-I, II, III & IV) using formulae of these respective units to be practiced.

Suggested Readings:

1. *Mathematical Methods for Physicists: Weber and Arfken, 2005, AcademicPress.*
 2. *Mathematical Methods for Physicists: A Concise Introduction: Tai L. Chow, 2000, Cambridge Univ.Press.*
 3. *Elements of Group Theory for Physicists by A. W. Joshi, 1997, JohnWiley.*
 4. *Group Theory and its Applications to Physical Problems by Morton Hamermesh, 1989,Dover*
 5. *Introduction to Mathematical Physics: Methods & Concepts: Chun Wa Wong, 2012, Oxford UniversityPress*
 6. *Introduction to Mathematical Probability, J. V. Uspensky, 1937, McGraw-Hill.*
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